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LAGRANGIAN MIXING IN WALL-BOUNDED TURBULENCE: A NETWORK PERSPECTIVE

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Turbulent mixing is undoubtedly a crucial mechanism in many natural phenomena and industrial applications involving turbulent flows. Due to its ability to enhance transport, turbulent mixing is a fundamental process to understand – among others – atmospheric dispersion, geophysical phenomena, as well as combustion mechanisms [1, 7]. In this work, to take advantage of the powerful capabilities of recent developments in network science, we propose a complex network-based approach to study turbulent mixing from a Lagrangian viewpoint [3]. In the last two decades, the application of complex networks has revealed several important insights in many research fields, including fluid flows [2, 4, 6, 8]. Here, we exploited a direct numerical simulation (DNS) of a fully-developed turbulent channel flow as a paradigm of possible applications. The DNS was run at $Re_\tau = Hu_\tau/\nu = 950$ for $T = 15200\nu/u_\tau^2$, where u_τ is the friction velocity, H is the half-channel height and ν is the kinematic viscosity [5]. A set of 100×100 fluid particles was initially released in the domain as a uniformly distributed grid in the plane (y^+, z^+) at $x^+ = 0$, where the streamwise, wall-normal and spanwise coordinates are (x^+, y^+, z^+) , respectively. To build the network, particles were grouped into $N_y = 100$ wall-normal levels corresponding to the network nodes, each one comprising a subset of $N_z = 100$ particles. At any time, connections between particle pairs are active based on their spatial proximity: a particle i is connected to a particle j if i lies inside a reference ellipsoid centred in j , and *vice versa* (by symmetry). The ellipsoid was selected to consider the anisotropy of the flow: its semi-axes were set proportional to the average pairwise Euclidean distance between all particles, so that the effect of the streamwise dispersion on particle positions is captured. As a result, we obtained a time-varying network, in which nodes represent the y^+ -levels, while link activation depends on the extent to which turbulent mixing affects particle dynamics. Since each node represents a set of N_z particles, each link is weighted, thus quantifying the interaction strength, E , as the total number of connections between particles in each node (see Fig.1a). The results show that the networks are fully able to capture the intensity of wall-normal mixing on particle dynamics, by highlighting characteristic mixing-advection regimes as well as the appearance of peculiar events (see Fig.1). Based on present findings, a promising tool is proposed, which can be exploited to extend the level of information of classical statistics for turbulence analysis.

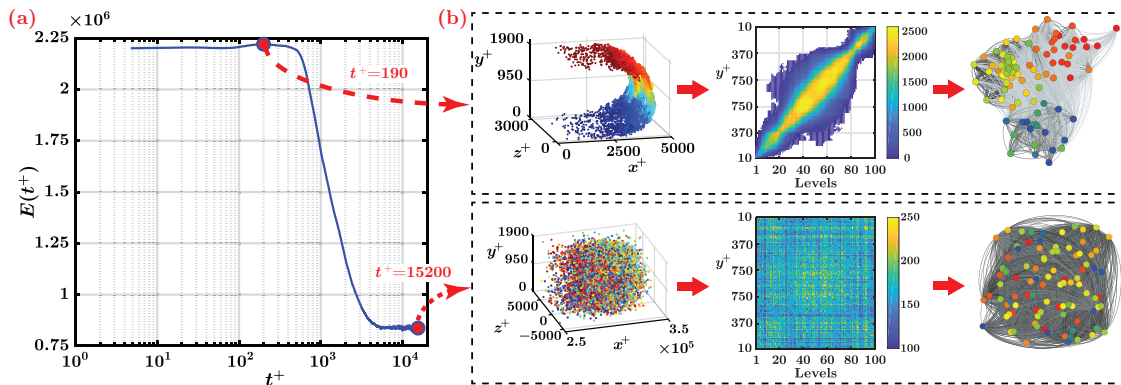


Figure 1. (a) Total number of particle connections, $E(t^+)$, as a function of time [3]. (b) From left to right: particle arrangement, link-weight matrix and corresponding network topology at $t^+ = 190$ (advection regime) and $t^+ = 15200$ (mixing regime). Node/particle colors indicate y^+ values of levels, from blue ($y^+ = 0$) to red ($y^+ = 1900$).

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